

November 6, 2018

SPECIAL PROVISION**SECTION 509 -- DRILLED SHAFTS****Item 509.1 – Mobilization and Demobilization of Drilled Shaft Drilling Equipment****Item 509.2 – Drilled Shafts****Item 509.3 – Obstruction Removal****Item 509.4 – Rock Socket Excavation****Item 509.51 – Crosshole Sonic Logging (CSL) Tests****Item 509.52 – Thermal Integrity Profiling (TIP) Tests****Item 509.62 – Drilled Shaft Reinforcing Steel****Description**

1.1 This work shall consist of furnishing all materials, equipment, labor, and services necessary to construct drilled shafts with rock sockets and permanent casing for the proposed US Route 4 over Bunker Creek bridge replacement as shown on the Base Technical Concept plans.

1.1.1 The permanent casing shall extend from the design cut-off grade to a minimum embedment of 6 inches into the bedrock.

1.2 The drilled shaft work will require coordination with the construction access, cofferdam construction and substructure excavation work at the pier site.

1.3 Subsurface Information. The Design-Build Team is advised to refer to Section 7.2 of the Technical Provisions for subsurface information.

1.4 Crosshole Sonic Logging (CSL) testing. The Design-Build Team shall provide the services of a qualified, independent, non-destructive testing Consultant for the purpose of providing CSL testing of drilled shafts under Item 509.51. The work includes furnishing all required test equipment and appurtenances, testing, analyses and reporting in accordance with ASTM D6760. Additional CSL testing may be performed by the Engineer using access tubes installed under this specification to verify results provided by the consultant. The CSL Consultant shall be the same entity as the TIP Consultant specified below.

1.5 Thermal Integrity Profiling (TIP) testing. The Design-Build Team shall provide the services of a qualified, independent, non-destructive testing Consultant for the purpose of providing TIP testing of drilled shafts using embedded thermal sensors under Item 509.52. The work includes furnishing all required equipment and appurtenances (including the thermal wire sensors), testing, analyses and reporting in accordance with ASTM D7949, Method B. The TIP Consultant shall be the same entity as the CSL Consultant specified above.

1.6 The reinforcing steel within the drilled shaft will be paid through Item 509.62 and includes the reinforcing steel cage that extends from the top of the longitudinal reinforcing layout to the bottom of the rock socket, as shown on the plans.

1.7 This work shall be conducted in conformance with all applicable environmental regulations and permits.

Materials & Equipment

2.1 Concrete. The Design-Build Team's mix design shall meet the requirements of Class AAA concrete in accordance with Section 520, except as modified herein. The slump shall be 8 inches plus or minus 1 inch after batching. The maximum aggregate size shall be 3/8 inches. The concrete shall be designed with the necessary admixtures to maintain the required slump and sufficient workability throughout the entire concrete placement. Air entrainment shall be between 4 and 7 percent.

2.2 Reinforcing Steel. Reinforcing steel used within the drilled shaft under Item 509.62 shall conform to the Section 544 requirements.

2.2.1 Clearance Spacers for Reinforcing Cage. Spacers used to provide the required sidewall and bottom clearance for the reinforcing cage shall be constructed of non-corrosive material that is equal in quality and durability to the shaft concrete, and shall be subject to approval. The spacers shall be of adequate dimension to ensure that the minimum clearance tolerances for the reinforcing cage are met, and that the reinforcing cage location is maintained during the concrete placement.

2.3 Permanent Steel Casing.

2.3.1 The permanent steel casing shall be steel pipe conforming to ASTM A252, Grade 2 or Grade 3, welded or seamless steel pipe and shall have minimum dimensions as shown on the plans. The casing shall also be of sufficient thickness and strength to withstand stresses from handling, installation, concrete pressure, surrounding earth and fluid pressures.

2.3.2 The straightness of the casing shall not deviate more than plus or minus 1/2 inch from a straight line over a 40 foot length. The length of the permanent casing shall be sufficient to extend from 6 inches below the lowest point of the bedrock surface to the drilled shaft cut-off elevation shown on the plans and stated in this specification, with splices being allowed. Casing splices shall have no interior splice plates and shall produce a true and straight interior face. Other attachments or connections made to the casing shall also produce a true and straight interior face. Rock cutting teeth or a cutting shoe shall be installed on the bottom of the casing to enable seating of the casing into bedrock.

2.4 CSL Access Tubes. The access tubes for the CSL testing shall consist of Schedule 40 steel pipe conforming to ASTM A53, Grade A or B, Type E, F or S. The inside diameter shall be at least 1.5 inches. All access tubes shall have a round inside surface free of defects and obstructions including all pipe joints. The access tubes shall be watertight, and free of corrosion

and other deleterious material that can prevent bonding with the concrete. All access tubes shall be fitted with watertight caps on the bottom and top.

2.5 Embedded Thermal Wire Sensors for TIP Testing. Embedded thermal wire sensors shall be provided with a sensor spacing of 12 inches. Sensors shall be digital and capable of operating in temperatures up to 220 degrees F.

2.6 TIP Data Collection System. Equipment shall be a fully automated data acquisition system for real-time monitoring and recording of temperature from multiple digital sensors versus time at user-defined intervals.

Construction Requirements

3.1 Qualifications. The Design-Build Team and the Design-Build Team's project superintendent for the drilled shaft work covered under this special provision shall have a minimum of three years' experience in constructing drilled shaft foundations within the past five years. The Design-Build Team's project superintendent shall be present at all times during execution of the work covered by this special provision. The Design-Build Team's drill operator shall have a minimum of two years' experience within the last four years. A summary of the experience and qualifications shall be submitted in writing to the Engineer at least four weeks prior to the start of the drilled shaft installation. The submittal shall include the name, address and phone number of the owner's representative who can verify the information provided. The Design-Build Team or any Firm engaged to perform the drilled shaft work shall be subject to approval by the Engineer.

3.1.1 CSL/TIP Consultant Qualifications. The same consultant shall be used for both CSL and TIP testing. The consultant(s) shall not be an employee of, or affiliated with, the drilled shaft or prime Design-Build Team and shall have documented experience conducting, analyzing, and reporting each test method on at least three drilled shaft projects of similar configuration and complexity over the past three years. The submittal shall clearly state the name, qualifications, and roles of all individuals who will be conducting the tests and/or performing the analyses with resumes provided. All aspects of the work shall be overseen by a New Hampshire licensed Professional Engineer.

3.2 Installation Plan Submittal. At least four weeks prior to constructing drilled shafts, the Design-Build Team shall submit an installation plan in accordance with 105.02 to the Engineer for review and approval. This plan shall be stamped by a New Hampshire licensed Professional Engineer knowledgeable in the design and construction of drilled shafts.

3.2.1 The Design-Build Team's submittal shall contain as a minimum, the following specific information:

- a. A complete description of the equipment and materials to be used, including manufacturer's specifications and catalog data for all rigs, drilling tools, casing, rock coring tools, cleaning equipment, pumps, concrete placement pipes, other necessary tools and clearance spacers.

- b. A description of the general drilled shaft construction method and sequence for each shaft, including mobilization of the drilling equipment, disposal of excavated soil and rock, disposal of water pumped from the drilled shafts, plans for locating support cranes, concrete pumping trucks and concrete trucks.
- c. Method of constructing the drilled shaft within the horizontal location tolerances. Details of frames and templates shall be provided.
- d. The methods of soil, obstruction and rock excavation including methods for seating the bottom edge of the temporary casing into bedrock.
- e. The method of drilled shaft construction, including the sequence of shaft construction at each shaft, details of the steel reinforcing cage lifting and installation, reinforcing steel connections, concrete placement procedures, means of separating the concrete from water within the concrete placement pipe, procedure for cutting the permanent casing to grade, CSL access tube installation, grout mix and grouting procedure, and TIP thermal wire sensor installation.
- f. Details of the proposed concrete mix design.
- g. Qualification submittals for the CSL/TIP Consultant.
- h. Description of all equipment used to perform the CSL and TIP testing including manufacturer, model numbers, and calibration verification.
- i. Description of all software used to perform the CSL and TIP analyses, including version.
- j. Procedures for installation of CSL access tubes and TIP thermal wire sensors and performance of CSL and TIP testing including data collection and recording, in-test analyses, post processing, and reporting.
- k. Methods of complying with all applicable environmental regulations.

3.2.2 The Engineer will evaluate the Installation Plan for conformance with the plans, specifications and this special provision. Within 21 days after receipt of the plan, the Engineer will notify the Design-Build Team of additional information or changes needed to meet the contract requirements. Approval of the installation plan shall not relieve the Design-Build Team of the responsibility to install the drilled shafts in accordance with the plans and specifications.

3.3 Subsurface Information. Rock core samples from the test borings are available for inspection by the Design-Build Team at the Materials and Research Bureau (phone number (603) 271-3151) upon request. It is the Design-Build Team's sole responsibility to make interpretations and draw conclusions with respect to the character of material to be encountered and its effect on the drilled shaft installation.

3.4 Pre-Drilled Shaft Construction Meeting. A meeting shall be held prior to initiating the drilled shaft construction. The purpose of the meeting shall be to review all aspects of the drilled shaft construction and to facilitate coordination between all parties involved. Individuals attending the meeting shall include the Engineer, the Project Engineer from the Bureau of Bridge Design, the Geotechnical Engineer from the Materials and Research Bureau, the Design-Build Team, the Firm performing the drilled shaft work, the CSL/TIP Consultant and all other personnel deemed appropriate by the previously mentioned personnel. The Bridge Design Project Engineer and the Geotechnical Engineer shall be notified at least 7 days in advance. The meeting shall be scheduled after the Installation Plan has been reviewed by the Engineer.

3.5 Drilled Shaft Tolerance. The drilled shafts shall be constructed to the following tolerances:

- a. The drilled shaft shall be within 3 inches of the plan position in the horizontal plane at the top of shaft elevation. (Note: the center of the drilled shaft is defined as the center of the reinforcing cage). Additionally, the minimum required clear distance indicated on the plans between the outside of the reinforcing cage and both the rock socket and permanent casing shall be provided.
- b. The vertical alignment of a drilled shaft excavation shall be within 2 percent of plumb over the total length of the shaft and rock socket.
- c. The excavation equipment and methods shall be designed so that the completed shaft excavation will have a planar bottom. The cutting edges of excavation equipment shall be normal to the vertical axis of equipment within a tolerance of 3/8 inch per foot of diameter.
- d. The bottom of the reinforcing cage shall be placed 6 inches, plus or minus 3 inches above the bottom of the shaft excavation. The bottom of the CSL tubes and TIP thermal wire sensors shall be at the same elevation as the bottom of the reinforcing cage.
- e. During concrete placement, the top of the reinforcing steel cage shall not move more than 1 inch above or below the plan position.
- f. The top elevation of the shaft concrete and permanent casing shall be no more than 1 inch above or below the plan position.

3.6 Drilling Equipment and Tools. The excavation and drilling equipment shall have adequate capacity including power, torque and down thrust to excavate a hole of both the maximum diameter and to a depth of 25 percent beyond the estimated lengths in the contract. The excavation equipment and tools shall be of adequate design, size and strength to perform the work as indicated on the plans or described herein. When the material encountered cannot be drilled using conventional drill buckets and earth augers with soil and rock teeth, the Design-Build Team shall provide special drilling equipment/procedures including but not limited to rock core barrels, rock tools, chisels, boulder breakers, air tools and other equipment necessary to construct the shaft excavation to the required depth.

3.7 Construction Methods.

3.7.1 The Design-Build Team shall perform the excavation required for the shafts, through whatever materials and groundwater that are encountered, to the dimensions and elevations shown on the plans or otherwise required by these special provisions, or as directed. The Design-Build Team's methods and equipment shall be suitable for the intended purpose and the materials encountered. Drilled shafts shall be constructed as indicated on the plans using the permanent casing construction method described below.

3.7.2 The shaft excavation down to the bedrock surface shall use casing methods to support the excavation. If slurry is used within the excavation, the slurry material, application and disposal shall meet all applicable environmental requirements. Any slurry materials that are used shall be completely flushed from the excavation until the return wash water is clean and free of fines prior to concreting the drilled shaft. Regardless of the shaft excavation support method that was used to reach the bedrock surface, the permanent casing shall be installed prior to initiating the rock socket excavation. The permanent casing shall be in place during the excavation for the rock socket and during concrete placement.

3.7.3 Permanent Casing Installation. The drilled shaft permanent casing shall be installed at the locations shown on the plans to within the tolerances set forth in 3.5. The bottom of the casing shall be seated a minimum of 6 inches into bedrock or deeper as needed to provide an effective seal at the bottom of the permanent casing, measured from the lowest bedrock elevation along the perimeter of the casing. Except for the seating of the permanent casing into bedrock, the casing may be advanced by twisting or rotating the casing into place using rotary drilling equipment, or by driving the casing with vibratory or impact hammers. Seating the casing into bedrock shall be accomplished by rotating the casing. Driving of the casing into bedrock shall not be permitted. The Design-Build Team shall be responsible for repair of any damage to the casing. Welding or thermal cutting of the permanent casing directly adjacent to the shaft concrete will not be permitted.

3.7.4 If the Design-Build Team elects to remove a casing from the shaft and substitute a longer casing, the excavation shall be backfilled before the substitution is made.

3.7.5 Oversize Temporary Casing. An oversize temporary casing with a diameter greater than the permanent casing that is installed around the permanent casing may be used during the drilled shaft construction. The bottom of the oversize casing shall not extend below the final bottom elevation of the permanent casing. The removal method of an oversize temporary casing shall not disturb the permanent casing seal into bedrock or the drilled shaft concrete, and shall be subject to approval. Removal of a temporary oversize casing within 72 hours after the initial set of concrete will not be permitted. Oversize temporary casing that cannot be removed in an approved manner shall be cut-off at an approved elevation and left in place at no cost to the Department.

3.7.6 The Design-Build Team shall modify drilling methods if any ground heaving, loss of ground, or damage to adjacent structures or services are observed. The adverse conditions shall be stabilized immediately and the Engineer shall be notified of such conditions within 24 hours. Any damage to adjacent facilities shall be repaired at the expense of the Design-Build Team.

3.8 Shaft Excavation.

3.8.1 The drilled shaft excavation consists of soil and obstruction removal, and bedrock excavation to create a rock socket. Drilled shaft excavations shall be made at the locations shown on the project plans. Excavations shall be made according to the dimensions shown on the plans, and within the tolerances set forth in 3.5. The top of rock socket is defined as the permanent casing final bottom elevation as determined and approved during the drilled shaft excavation. Excavation methods that result in disturbance of lateral support materials surrounding the shaft or below the shaft shall not be used. Dewatering of the shaft excavation for excavation or inspection purposes will not be required. All excavated materials shall be disposed of in an approved manner.

3.8.2 Soil Excavation. Soil excavation is defined as all the material above the approved top of rock socket as defined above that is not classified as an obstruction. Excavation of the soil shall be performed with conventional drilling tools as described above. Material that in the judgment of the Engineer cannot be removed after reasonable effort using conventional tools shall be considered as an obstruction and shall be treated as described below. Reasonable effort shall include operating the approved drilling equipment at maximum power, torque and down thrust for a period of at least 15 minutes.

3.8.3 Obstruction Removal. Obstructions shall be defined as any natural material or man-made objects above the approved top of rock socket that cannot be removed by conventional excavation methods and tools described above. Bedrock that is removed within the permanent casing seating depth down to the approved top of the rock socket shall be classified as obstruction removal. Drilling tools lost in the excavation will not be considered obstructions and shall be removed by the Design-Build Team without compensation. Special drilling tools or removal procedures described above that are not detrimental to the shaft excavation shall be employed by the Design-Build Team to remove obstructions. Blasting of obstructions will not be permitted. The Design-Build Team shall provide the necessary means to accurately measure the obstruction lengths and all measurements shall take place in the presence of the Engineer.

3.8.4 Rock Socket Excavation. Rock socket excavation is defined as all excavation that extends below the approved top of the rock socket as defined above. The rock socket shall be constructed with the minimum rock socket length indicated in the plans, or deeper, if ordered. The rock socket diameter shall be within the tolerances set forth in 3.5. Methods and tools used to excavate the rock socket shall include, but are not limited to the special methods described above. Blasting for the rock socket excavation will not be permitted.

3.8.5 Shaft Excavation Acceptance.

3.8.5.1 A shaft excavation including the rock socket will be accepted by the Engineer based on the results of a visual inspection, observation of the drilling operation, and review of the Design-Build Team records.

3.8.5.2 Visual acceptance of the shaft excavation by the Engineer shall be required prior to placement of the steel reinforcement cage and concrete. The completed shaft excavation shall be thoroughly cleaned of all sediment including loose soil, debris and loose or pulverized bedrock

prior to inspection. The excavation bottom shall be cleaned so that a minimum of 50 percent of the base will have less than 1/2 inch of sediment and at no place on the base more than 1-1/2 inches of sediment.

3.8.5.3 Dewatering of the excavation for inspection purposes will not be required. The Design-Build Team shall make the completed excavation available to the Engineer for inspection. The Design-Build Team shall also provide suitable access for inspection, safety lines and equipment, communication equipment, electric power, and devices for checking dimensions, alignment and plumbness as needed.

3.8.5.4 Should the Engineer have reason to believe that the drilled shaft excavation techniques or workmanship has been deficient with respect to a given shaft excavation such that the integrity of the excavation is in question, work on the drilled shaft shall be stopped. The Design-Build Team shall not proceed with the shaft excavation in question or any subsequent shaft excavations until the deficient excavation techniques or workmanship have been changed to the Engineer's satisfaction.

3.9 Steel Reinforcement Construction and Installation.

3.9.1 The drilled shaft reinforcing steel, which includes longitudinal bars and transverse bars or spirals and mechanical connectors, shall be assembled into a cage along with stiffeners, spacers, CSL access tubes, and TIP thermal wire sensors prior to installation according to the plans. The reinforcing bars shall be 100 percent tied and braced sufficiently to allow lifting and installation as a single unit without damage, racking or deformation. Splicing of the longitudinal bars shall not be allowed, except using approved mechanical connectors within the limits indicated on the plans. The reinforcement cage shall be placed into the shaft excavation to within the horizontal and vertical tolerances described in 3.5.

3.9.2 Spacers and other means as necessary shall be used to maintain the horizontal tolerance criteria set forth in 3.5. The spacers shall be securely attached to the reinforcing cage and shall be in firm contact with the sidewalls of the casing and rock socket excavation. The spacers shall be used at regular intervals of 5 feet or less. When the diameter of the longitudinal reinforcing steel exceeds one inch, such spacing may be increased to a maximum of 10 feet. Each shaft shall have a minimum of 2 rows and 3 vertical lines of spacers. The spacers shall be dimensioned to meet the tolerance criteria set forth in 3.5.

3.9.3 An approved method to restrain the upward and downward movement of the reinforcing cage shall be used to prevent uplift or downdrag of the cage during concrete placement. The elevation of the top of the reinforcing steel shall be checked before and after the concrete is placed. If movement greater than that allowed under 3.5 has occurred, the drilled shaft shall be considered defective and corrective measures shall be undertaken by the Design-Build Team to the satisfaction of the Engineer. No additional shafts shall be constructed until the Design-Build Team has modified his restraining system to prevent the uplift or downdrag problem from reoccurring. Corrective measures shall be the responsibility of the Design-Build Team and shall be at no cost to the Department.

3.10 Installation of CSL Access Tubes. Six CSL access tubes shall be installed at an equal 60 degree spacing along the inside perimeter of the reinforcement cage. The tubes shall be securely attached to the interior of the reinforcement cage and shall be as near to vertical and parallel as possible. The tubes shall extend from the bottom of the reinforcing cage to at least 3 feet above the drilled shaft work surface, or to a top elevation as directed. The tubes shall be filled with potable water in non-freezing conditions and with an approved non-toxic anti-freeze in freezing conditions prior to or immediately after concrete placement to prevent debonding of the access tubes with the concrete. The bottom of the CSL tube shall be securely capped, and the top of the tube shall be temporarily capped prior to placement of the drilled shaft concrete. Care shall be taken in the removal of the caps after concrete placement to not apply excessive torque or other stresses that could break the bond between the tubes and the concrete.

3.11 Installation of TIP Thermal Wire Sensors. Tip thermal wire sensor installation shall be performed under the supervision of the CSL/TIP Consultant. Six TIP thermal wire sensors shall be installed at an equal 60 degree spacing along the inside perimeter of the reinforcement cage. The thermal wire sensors shall not be in contact with the CSL access tubes and shall be securely attached to the interior of the reinforcement cage as near to vertical and parallel as possible. The wire sensors shall extend from the bottom of the reinforcing cage to at least 3 feet above the drilled shaft work surface, or to a top elevation as directed. Care shall be taken to ensure that sensor levels along each wire correspond to the same depth (elevation) as the other wires. Wires shall be identified by number and wire positions shall be documented to enable proper The thermal wire sensors shall not be damaged during installation of the reinforcement cage.

3.12 Concrete Placement. Applicable portions of Section 520 shall be followed for concrete placement, except as modified herein. Either the free fall method or underwater placement method shall be used, as defined below. For both methods, the concrete shall be placed in one continuous operation from the bottom of the shaft to the design top of shaft concrete plus any concrete overpour as described in 3.12.2.8. Cold joints in the concrete will not be allowed unless approved.

3.12.1 Concrete Placement – Free Fall Method.

3.12.1.1 The free fall method of concrete placement will only be allowed in a cased, dry excavation. A dry excavation shall be defined as having a water depth of 3 inches or less at the time of initial concrete placement. Excavations that have a greater depth of water or measurable seepage shall be flooded and concreted using underwater placement procedures. Prior to concrete placement using the free fall method, the Design-Build Team shall demonstrate that no seepage occurs into the excavation at the highest river level that can be expected during the initial concrete set period.

3.12.1.2 Free falling concrete shall be placed at the center of the excavation using a hopper with attached hose, or other approved system that centers the concrete fall into the excavation. The maximum concrete drop height shall be limited to a height that is less than 50 feet. Shorter drop heights and other adjustment in the placement procedure shall be required as directed, to prevent the concrete from striking the reinforcing cage during placement.

3.12.2 Concrete Placement – Underwater Method.

3.12.2.1 Underwater placement procedures shall be required within excavations where the criteria for a dry excavation and free fall placement methods cannot be met. The underwater placement method consists of placing the concrete below the water at the bottom of the drilled shaft excavation, using either tremie or pumping methods and equipment as defined below. The water level within the drilled shaft shall be at a stabilized, static level at the time of concrete placement.

3.12.2.2 Concrete Placement Pipe. The placement pipe used for the tremie or pumping methods shall consist of a steel or iron tube of sufficient length and diameter to discharge concrete at the bottom elevation of the excavation. Aluminum pipe will not be permitted. The minimum pipe diameter shall be 10 inches for the tremie placement method and 5 inches for the pumping placement method. The length of the placement pipe shall be clearly marked in one foot increments along the outside of the pipe, measured upward from the discharge end. The inside and outside surfaces of the tremie pipe shall be clean and smooth to permit both flow of concrete and unimpeded withdrawal during concrete placement. The wall thickness of the pipe shall be adequate to prevent crimping and bending. The pipe wall and joints shall be strong enough to resist concrete pumping pressures and shall be watertight.

3.12.2.3 The discharge end of the placement pipe shall be equipped with a watertight valve or disposable plate that prevents water from filling the interior of the pipe when inserted into the excavation. Alternately, a plug that maintains separation between the concrete and water within the pipe may be used at the top of the pipe. The valve, plate or plug shall provide a seal in the pipe until concrete discharge begins, in order to minimize contamination of the concrete. Disposable plates or plugs shall be of a material non-detrimental to the drilled shaft, as approved by the Engineer. Air inflated plugs shall not be used. The discharge end of the pipe shall be designed to allow free radial flow of concrete during placement operations.

3.12.2.4 The placement pipe shall be installed in the center of the shaft excavation and extend to the bottom of the excavation. The pipe shall be properly secured and braced within the excavation to prevent uplift or drift during concrete discharge. The pipe and bracing shall be designed to allow progressive and steady removal as the concrete fills the excavation. Methods to remove air trapped in tremie or pump pipes shall be provided if necessary, as determined by the Engineer.

3.12.2.5 The Design-Build Team shall maintain the concrete in a workable state throughout the entire underwater placement operation. In addition to designing the concrete mix with any necessary admixtures, the Design-Build Team shall lubricate the pumping system and cool the placement pipes as necessary, in order to maintain acceptable workability of the concrete. The initial truck load of concrete shall be sampled at the discharge end of the pumping system and tested for slump, prior to pumping the concrete into the placement pipe. Concrete that has lost sufficient workability to the extent that the provisions of this specification cannot be met will result in rejection of the drilled shaft.

3.12.2.6 The placement pipe discharge end shall be immersed in at least 7 feet of concrete at all times after the start of concrete placement. The flow of concrete in the pipe shall be

continuous, and a positive pressure differential shall be maintained at all times to prevent water or slurry intrusion into the pipe. If at any time during concrete placement the pipe discharge orifice is removed or uplifts from the fluid concrete with concrete discharge occurring, the entire drilled shaft shall be considered defective. In such a case, the Design-Build Team shall completely remove the reinforcing cage and concrete by approved methods. The shaft shall then be re-excavated according to these provisions. All costs for replacement of defective shafts shall be the responsibility of the Design-Build Team and shall be at no cost to the Department. If concrete discharge has not occurred, then the placement pipe shall be re-immersed into the concrete with a closed valve or disposable plate or plug on the discharge end.

3.12.2.7 The concrete level within the permanent casing shall be monitored inside and outside the reinforcing cage throughout the placement to verify that the concrete is spreading uniformly across the drilled shaft. The Design Build Team shall implement corrective measures in the event that a differential height of concrete between the inside and outside of the reinforcing cage is measured.

3.12.2.8 In cases where the concrete cutoff grade is below the working surface, the concrete shall be placed a minimum of 2 feet above the proposed top elevation of concrete, unless otherwise approved. The excess 2 feet of concrete shall then be removed back down to the proposed concrete grade, or lower if necessary to reach sound concrete, using chipping or other approved methods.

3.12.3 Immediately after completion of the concrete placement, the drilled shaft shall be sufficiently disconnected from any structural templates, trestles, barges or other sources of movement and vibration to prevent the direct transfer of movement and vibration from these sources to the shaft. This requirement shall be in effect until the drilled shaft concrete has achieved a strength of at least 3500 psi, unless otherwise approved.

3.12.4 Adjacent construction activities that cause vibrations shall not be permitted within a minimum clear distance of 20 feet from a freshly concreted shaft, until the concrete has achieved a sufficient initial set to prevent disturbance of the concrete. The initial set time shall be as approved, and shall be a minimum of 24 hours, or longer if concrete admixtures have been used to delay the concrete set.

3.13 Nondestructive CSL and TIP Testing. CSL and TIP testing of the concreted drilled shaft shall be performed by the CSL/TIP Consultant in accordance with ASTM D6760 and D7949, respectively. Additional CSL testing may be performed by the Engineer using the access tubes installed under this specification to verify results provided by the consultant.

3.13.1 Pre-CSL/TIP Testing Meeting. A meeting shall be held at the site prior to any testing by the CSL/TIP Consultant. Scheduling of the meeting on the day of the actual CSL/TIP testing is acceptable. The purpose of the meeting shall be to review the CSL/TIP testing program and equipment and to provide coordination between personnel involved with the testing. Individuals attending the meeting shall include the Engineer, the Geotechnical Engineer from the Materials and Research Bureau, the Design-Build Team, the CSL/TIP Consultant and all other personnel deemed appropriate by the previously mentioned personnel. The Geotechnical Engineer shall be notified at least 7 days in advance.

3.13.2 Design-Build Team Assistance. The Design-Build Team shall assist as required during the CSL and TIP testing. This includes providing adequate time for performing the test, a stable and reasonable means of access to the drilled shafts, any necessary support personnel, equipment, materials and power source.

3.13.3 Performance of CSL Testing. The concrete within the tested drilled shaft shall have cured a minimum of 72 hours prior to testing. The CSL testing shall be carried out with the source and receiver probes in the same horizontal plane, unless test results indicate potential anomalies or defects, in which case the questionable zone shall be further evaluated with angled tests. The CSL testing shall be performed between all perimeter tubes and between all combinations of diagonal tubes. The CSL measurements shall proceed from the bottom of a pair of access tubes to the top in increments of 2 inches. The probes shall be pulled simultaneously over the depth being measured with all slack removed from the cables. The access tubes shall be grouted with approved materials and methods, after the shaft has been completed and approved.

3.13.3.1 Interpretation of CSL Data and Reporting of Test Results. The preliminary results of the CSL testing shall be evaluated and discussed with the Engineer at the site on the day of testing. The final CSL results shall be presented in a report in accordance with ASTM D6760. All anomalies or defect zones shall be interpreted and discussed in the report along with recommendations for remediation.

3.13.4 Performance of TIP Testing. TIP data shall be collected and recorded at 15 minute intervals beginning with the onset of concrete placement and terminating no fewer than 12 hours after the peak temperature of the concrete has been reached, or as directed by the Engineer.

3.13.4.1 Interpretation of TIP Data and Reporting of Test Results. The preliminary results of the TIP testing shall be evaluated and discussed with the Engineer at the site on the day of testing. The final TIP results shall be presented in a report in accordance with ASTM D7949. All anomalies or defect zones shall be interpreted and discussed in the report along with recommendations for remediation.

3.14 Acceptance of Completed Drilled Shaft. The final acceptance of each drilled shaft shall be the decision of the Engineer based on the conformance to tolerance limits set forth in 3.5 and the results of CSL and TIP testing. If the drilled shaft integrity is questionable, the Engineer may require a core hole through the shaft to evaluate its condition. If a defect is confirmed, the Design-Build Team shall pay for all coring costs. If no defect is encountered, the Department shall pay for all coring and grouting costs. If a shaft is deemed unacceptable, the Design-Build Team shall submit a plan for remedial action with calculations and working drawings prepared and stamped by a New Hampshire licensed Professional Engineer. Materials and work required to perform remedial shaft actions, including engineering analysis and redesign, shall be provided at no cost to the Department.

3.15 Design-Build Team's Records.

3.15.1 The Design-Build Team shall keep a record independent of the Engineer's record of all pertinent data relative to the installation of the drilled shaft. This record shall be available for

the Engineer's inspection, and shall be transmitted as directed. The Design-Build Team's record shall include the following:

- a. Shaft location and dates of installation
- b. Slurry data including test data
- c. Total length of each shaft, including the top and bottom elevations of the permanent casing and any temporary oversize casing that is used during the drilled shaft construction
- d. Verticality of shaft
- e. Placement and condition of the reinforcing cage
- f. The time, method and duration of the concrete placement, with a log of the temperature at the time of placement
- g. The quantity of concrete versus the height of the filled shaft

3.15.2 The Design-Build Team shall also maintain a construction method log during shaft excavation. The log shall contain information for the top and bottom elevation of each soil and obstruction layer, the bedrock surface elevation, ground water depth, drilling rate and remarks. The log shall be provided to the Engineer a minimum of 24 hours prior to concreting the drilled shaft.